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In vivo visualization of the PICA perfusion territory with super-selective pseudo-continuous arterial spin labeling MRI

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ABSTRACT

In this work a method is described to discern the perfusion territories in the cerebellum that are exclusively supplied by either or both vertebral arteries. In normal vascular anatomy the posterior inferior cerebellar artery (PICA) is supplied exclusively by its ipsilateral vertebral artery. The perfusion territories of the vertebral arteries were determined in 14 healthy subjects by means of a super-selective pseudo-continuous ASL sequence on a 3 T MRI scanner. Data is presented to show the feasibility of determining the PICA perfusion territory. In 10 subjects it was possible to accurately determine both PICA perfusion territories. In two subjects it was possible to determine the perfusion territory of one PICA. Examples in which it was not possible to accurately determine the PICA territory are also given. Additionally, the high variability of the extent of the PICA territory is illustrated using a statistical map. The posterior surface of the cerebellum is entirely supplied by the PICA in six subjects. The most posterior part of the superior surface is supplied by the PICA in eight subjects, and the inferior half of the anterior surface in six subjects. The inferior part of the vermis is supplied by the PICA in all subjects. Two subjects were found with interhemispheric blood flow to both tonsils from one PICA without contribution from the contralateral PICA. With the method as presented, clinicians may in the future accurately classify cerebellar infarcts according to affected perfusion territories, which might be helpful in the decision whether a stenosis should be considered symptomatic.

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Introduction

In the brain, the ability to visualize arterial perfusion territories is important for many clinical applications (Hartkamp et al., 2012). Perfusion territories are widely variable among individuals (Lee et al., 2004; van Laar et al., 2006), which also holds true for the cerebellum. This was demonstrated by the injection of India ink into the vertebrobasilar sytem of post-mortem human brains (Marinković et al., 1995). As such, the wide variability of the posterior inferior cerebellar artery (PICA), anterior inferior cerebellar artery (AICA), and superior cerebellar artery (SCA) was documented on schematic figures of the three (posterior, anterior, and superior) surfaces of the cerebellum. An atlas providing better visual correlation with clinical neuroimaging was later created, showing standard arterial perfusion territories in 12 axial sections through the brain stem and cerebellum (Tatu et al., 1996). Although this perfusion territory atlas is still in general use, its clinical applicability is hampered by the wide inter-individual variability of cerebellar perfusion territories. It does not allow an accurate distinction of the different arterial perfusion territories in an individual patient, necessitating the visualization of cerebellar perfusion territories in vivo. Arterial spin labeling (ASL) MRI is a non-invasive technique to image brain perfusion without the need of administering an exogenous contrast agent (Hendrikse et al., 2012). There are multiple ASL methods available, which frequently can be modified to allow for the mapping of perfusion territories by introducing variations in perfusion signal between different feeding arteries (Hartkamp et al., 2012).

In the present study, we aim to demonstrate the ability of super-selective pseudo-continuous arterial spin labeling (p-CASL) MR imaging (Helle et al., 2010, 2013) to distinguish the cerebellar perfusion territory of the PICA. We postulate that a selective labeling of each vertebral artery can distinguish the territories that are exclusively fed by one vertebral artery (PICA in normal vascular anatomy) from those territories supplied by both vertebral arteries (AICA and SCA) due to mixing in the basilar artery.

Abbreviations: AICA, anterior inferior cerebellar artery; ASL, arterial spin labeling; BA, basilar artery; CoW, circle of Willis; p-CASL, pseudo-continuous ASL; PICA, posterior inferior cerebellar artery; SCA, superior cerebellar artery; VA, vertebral artery; VBS, vertebrobasilar system.

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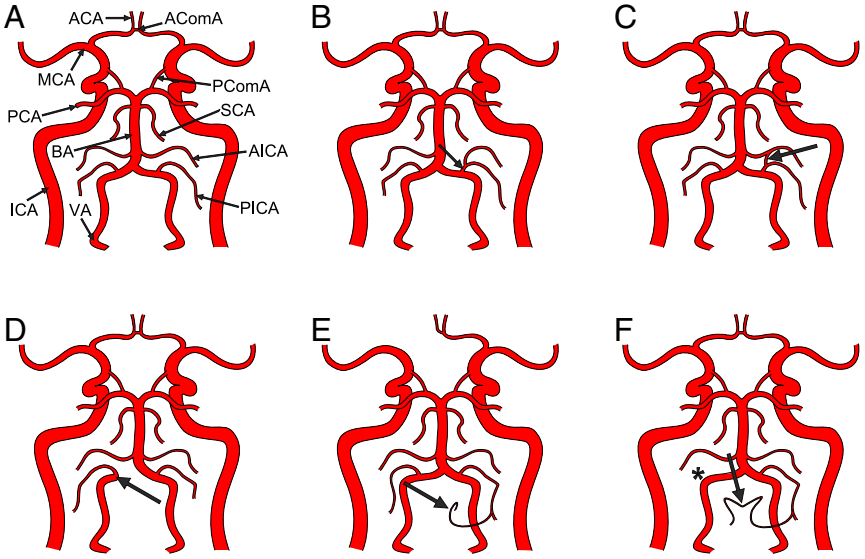

Fig. 1. Schematic overview of the circle of Willis (CoW) and the vertebrobasilar system (VBS) with a normal vascular anatomy (A) and several variants (B–F) in which segments of vessels (D–F) may be missing or anastomosis between vessels are depicted (C and F). Two variations are shown (B and C) in which the AICA also receives blood from the VA due to sharing a common trunk with the PICA (B, arrow) and due to the presence of an anastomosis between the AICA and PICA (C, arrow). One variant is shown with the VA functionally ending in the PICA (D, arrow), which may occur with either a hypoplastic or missing segment of the VA after the origin of the PICA. Two variant types are shown (E and F) in which arteries may supply blood crossing the cerebellar midline: a distal branch of the PICA with a tonsillar loop (E, arrow) and an interhemispheric anastomosis (F, arrow); additionally in the last example a missing PICA is depicted contralaterally (F, star).

Methods

This study was approved by the institutional ethical review board and informed consent was obtained from the individual participants. Fourteen healthy volunteers (5 male; age, 27 ± 4 years) were investigated on a 3 T MRI scanner (Achieva, Philips Medical Systems, The Netherlands).

Imaging protocol

The MR protocol consisted of a sagittal localizer, time-of-flight MR angiogram (MRA), anatomical T_1-weighted imaging, and included four super-selective p-CASL sequences for both right (RICA) and left (LICA) internal carotid arteries, and right (RVA) and left (LVA) vertebral arteries. The super-selective p-CASL sequences were performed as

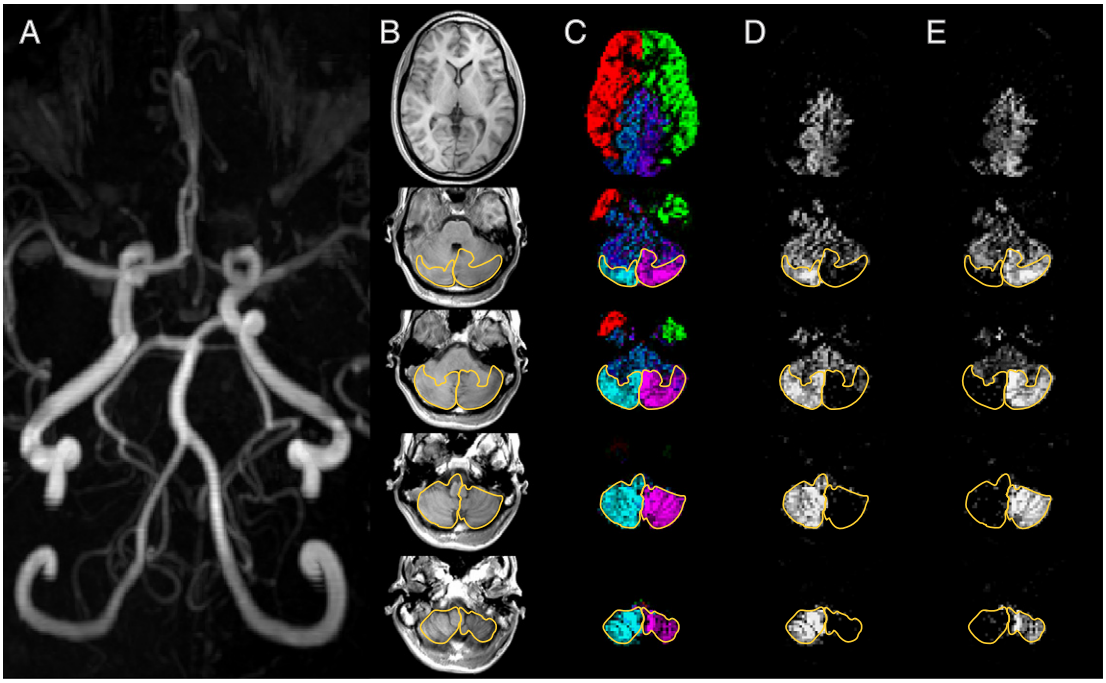

Fig. 2. Time-of-flight MRA images (A) of the vertebral arteries (VAs) and circle of Willis show the presence of all vessels as illustrated in Fig. 1A, albeit with a slightly dominant left VA. Anatomical T_1 weighted images (B) through the cerebellum from inferior (bottom row) to superior (top row). Territorial perfusion images (C) show the territory supplied by the right (cyan) and left (magenta) VAs, and by the right (red) and left (green) internal carotid arteries. With the mixing of blood in the basilar artery, cyan and magenta turn into blue. Individual perfusion images of the right (D) and left (E) VAs. The posterior inferior cerebellar artery (PICA) territories are outlined in perfusion images (C–E) and copied to the anatomical images (B). The PICA territories can be easily discriminated; they are symmetrical, and supply the inferior cerebellar surfaces (B).

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